Meeting summary:

National Earthquake Prediction Evaluation Council (NEPEC)

1 September 2016, 12:00 to 2:00 PM EDT, via phone and Webex

Main topics:

1. Completion of NEPEC statement on proper posing and testing of earthquake predictions.
2. Updates on previous topics.
3. Chair transition.

Note: Copies of presentations noted below available on request to Michael Blanpied <mblanpied@usgs.gov>.

Agenda:

The meeting was opened at 12:05 PM, with members, speakers and guests joined by phone and logged into a Webex session for sharing of slide presentations. After a roll call (attendees are listed at the end of this summary) and review of the agenda, Mike Blanpied and Bill Leith thanked and praised Terry Tullis for his outstanding service as chair of the NEPEC, and welcomed Roland Bürgmann to the chairmanship.

Discussion of draft NEPEC statement, with goal of completing for delivery to USGS

Tullis asked members for comments on a draft report, "Evaluation of Earthquake Predictions," which the council has prepared at the request of USGS. Hearing no comments, Tullis thanked a writing team that had led the final phase of document development, and declared the document final and approved.
Decision: NEPEC declared final their opinion document, "Evaluation of Earthquake Predictions."
Action: Tullis to send the report with cover letter to USGS Director Suzette Kimball.

Update on Pacific Northwest earthquake communication plan development

Joan Gomberg summarized progress of a project that aims to create an earthquake risk communications plan for the Casacadia region encompassing the western reaches of Washington, Oregon, northern California and British Columbia. NEPEC had earlier identified the need for such a plan, noting that it will be challenging for earthquake science experts residing in many federal, state and private institutions to swiftly agree on data interpretation and conclusions when faced with "situations of concern" such as a large offshore earthquake, large subduction interface creep event, or maverick earthquake prediction that catches public attention. They also noted the challenge of identifying which decision-makers would be aided by authoritative scientific information, and ensuring that such information made it into the right hands, in usable form, on short time scale. The need for a risk communication plan was endorsed in later discussions with state geologists, state emergency managers, and others involved in earthquake crisis response and communication. The Cascadia Region Earthquake Workgroup (CREW), a public-private coordination body, is leading development of the plan with funding from the USGS Earthquake Hazards Program and USGS SAFRR project. CREW has contracted with The Resilience Institute (TRI) at Western Washington University to conduct workshops and compose the communication plan. In support of the project, Gomberg led development of a USGS report, suggested by NEPEC, on *Earthquake Forewarning in the Cascadia Region* (2015 USGS open-file report), to serve as a background for workshop participants, and also serves as USGS liaison to the project. Slides from her presentation are archived in file *NEPEC_01Sept2016_Gomberg_PNW-messaging-project.pdf* on the NEPEC web site.

Gomberg outlined the process undertaken by CREW and TRI to create the risk communication plan. Key steps include determining under what circumstances there is a need for scientific notifications to users; what

audiences should receive what messages; whether there is a need for pre-scripted message templates; information pathways for messages; and mechanisms for message exchange. The project organized a literature review and a survey on best practices, and convened podcasts and webinars to provide project participants with background information. It then held two workshops, in Seattle, WA and Salem, OR, that brought together participants with expertise in geoscience, communications and public outreach, and representatives from the private sector. Gomberg provided draft summaries from both workshops, and said that TRI staff are currently writing an initial report draft. In addition to the goals summarized above, project leaders wish the resulting document to serve as a template for other regions.

Key recommendations from the Seattle and Salem workshops include: advance coordination and planning is needed to insure rapid and useful communication and to minimize conflicting information; there would be merit in creating a regional advisory body to include government scientists, academics, social scientists, emergency managers, public information officers, and tribal representatives (there was considerable discussion of the appropriate size, make-up and name of such a group, yet to be determined); there are several categories of situations that might require either region-wide or more local implementation of the plan to create and deliver advisory messages. CREW plans to deliver two documents by the end of 2016: a report on Regional Issues and Perspectives on Coordinated Earthquake Advisory Messaging, and the Cascadia Regional Earthquake Coordinated Messaging Plan.

Operational forecasting developments

The Council received several briefings on research and development of methods and procedures for operational earthquake forecasting (OEF) and operational aftershock forecasting (OAF).

Morgan Page summarized the findings of a paper by herself and others on global generic models of aftershock productivity. Such models can provide an initial aftershock forecast immediately following an earthquake, with forecast model parameters drawn from an analysis of historical seismicity in the region. The paper is to be published in the October, 2016 issue of the BSSA (*Bulletin of the Seismological Society of America*) (doi: 10.1785/0120160073). Slides from Page's presentation are archived in file *NEPEC_01Sept2016_Page_Global-Omori.pdf* on the NEPEC web site. In discussion, John Vidale noted that areas such as the Pacific Northwest may need a finer scale of regionalization to capture variations in aftershock productivity; Page explained that the parameter model can accommodate such improvements. There was also a discussion of earthquakes with depths below 50km, which were omitted from Page et al.'s analysis, with the opinion expressed that addressing those deeper earthquakes would be an important future step.
Informal NEPEC recommendation: Consider expanding the statistical analysis to include deeper earthquakes.

Ned Field and Jeanne Hardebeck explained the path of development to an operational aftershock forecasting system at the USGS. Forecast algorithms have been coded within the OpenSHA software platform. The next phase will add the capability for those algorithms to automatically trigger on the occurrence of an earthquake, and to account for the evolving aftershock sequence in calculating forecasts updates. Forecasts will be posted to an internal web site, with the ability of authorized users to push forecasts to the public web site. In discussion, Roland Bürgmann asked about plans for testing. Hardebeck explained that the USGS plans to run the system in a testing mode for some months, performing retrospective tests and evaluating forecast performance before reaching the point that forecasts will be automatically released. She also said that performance metrics would need to be defined. Gail Atkinson asked if a beta version would be made available to NEPEC, and that was confirmed, with the additional comment that the nature and timing of NEPEC's official review of the system, including future algorithm improvements, will need to be defined. Field said that the "generic" forecasts—based on mainshock magnitude and previously determined parameter values—were ready for use with only modest additional

testing needed, and that it remained to be seen how much additional value is gained through the calculation of forecast updates using sequence-specific parameters.
USGS Action: USGS to define the role and timing of NEPEC's review of new operational aftershock forecasting methods and related performance testing results.

Ned Field briefed the Council on the development of a full time-dependent earthquake rupture forecast (ERF) for California, called UCERF3-ETAS. This model adds earthquake clustering to the existing longer-term, time-dependent UCERF3, with the short-term behavior described through an implementation of the ETAS clustering model. UCERF3-ETAS is designed to include both on-fault and off-fault seismicity, with the potential for generating a host of forecast types, including aftershock forecasts, time-dependent mainshock forecasts, and time-dependent hazard and loss forecasts. An initial implementation of UCERF3-ETAS is described in a paper accepted for publication pending revisions, and an additional paper is in development on potential uses of the model for operational loss forecasting.

The USGS will request NEPEC recommendations on the next steps in UCERF3-ETAS development. Further development would require significant staff resources as well as continued access to IT developer expertise and to high-performance computers. Following advice received previously from both NEPEC and the Senior Earthquake Studies Advisory Committee (SESAC), development will be guided in large part by demonstrated user need. Field encouraged NEPEC members to attend an April 2017 Powell Center workshop that will bring together UCERF3-ETAS project leads with potential "first adopter" users. Additional questions to NEPEC will likely include: Is this modeling approach the most promising? Is the model good enough to be useful, and useful enough to be worth operationalizing? Who are the potential users of forecasts based on UCERF3-ETAS? And is it worth exploring a public-private partnership to support this work?

In a brief period of discussion, John Vidale asked whether there are linkages between OEF and earthquake early warning (EEW). Field replied that and OEF model like UCERF3-ETAS could provide priors in the form of time-dependent likelihoods of each potential rupture source, which could be used to tune the EEW model in real time. Gail Atkinson suggested that there be included a means by which to incorporate post-earthquake information into the OEF model. Evelyn Roeloffs asked if the UCERF3-ETAS paper could be provided, and Field replied that he would supply both that and the loss modeling paper being written as soon as available.
USGS Action: Send to NEPEC the UCERF3-ETAS paper to appear in BSSA.

Nick van der Elst summarized development of an ETAS-based aftershock forecasting method. (Slides from his presentation are archived in file *NEPEC_01Sept2016_Elst_Spatial-forecasts.pdf* on the NEPEC web site.) As discussed in the September 2015 NEPEC meeting, aftershock forecasting based on the methods of Reasenberg and Jones (1989) have certain shortcomings, including the inability to adapt to large aftershocks and lack of a spatial component amenable to maps or location-based forecasting. The ETAS (epidemic-type aftershock sequence) methodology overcomes those problems by automatically adjusting to the evolving aftershock sequence (including large events that spawn their own aftershocks), and supports spatial forecasting to produce forecast maps. The ETAS model has been successfully field-tested by USGS following the M7.8 Ghorka, Nepal earthquake, and has performed well in prospective testing by the Collaboratory for Study of Earthquake Predictability (CSEP). Furthermore, the ETAS approach offers more accurate estimates of forecast uncertainty.

Van der Elst leads a three-year project jointly supported by the USGS and by the USAID Office of Foreign Disaster Assistance, which aims to build a package of aftershock forecasting software and forecast products that can both be implemented by the USGS and be shared with international partners. An initial partner in development is the Director of Civil Protection in Baja California. The project will create an underlying

open-source software suite built within OpenSHA, a user-friendly GUI interface, and forecast products. The USGS will work with Mexico's CICESE and Baja's civil protection staff to hold workshops to identify uses of aftershock forecasts in decision-making and to design forecast messaging for those audiences. USGS staff are also in initial discussions with FEMA and hope to establish a partnership in this work. In discussion, van der Elst confirmed that the forecast model will require extensive testing, including a full exploration of model sensitivity to ETAS parameter uncertainties. Vidale encouraged the USGS to consider forecasts of aftershock ground shaking probability in addition to forecasting aftershock occurrence.

Closing discussion

The closing discussion returned to the question of NEPEC's role in providing guidance and recommendations relating to UCERF3-ETAS and related model development and operationalization. It may make sense to follow the approach used for NEPEC review of the UCERF2 and UCERF3 models, wherein the Council was provided with information about what technical reviews were done, and how comments were handled, rather than performing an in-depth technical review. It was noted that the UCERF projects included a Scientific Review Panel (SRP) that has not been established in the case of UCERF3-ETAS.
Action: Bürgmann and Blanpied to discuss how to handle a NEPEC review of UCERF3-ETAS.
Action: Blanpied to poll members for availability to attend the April Powell Center workshop.

The meeting was adjourned at 2:00 PM.

Members:

Roland Bürgmann, UC Berkeley *(incoming Chair)*
Terry Tullis, Brown University *(outgoing Chair)*
William Leith, USGS, Reston *(Co-chair)*
Ramon Arrowsmith, ASU *(did not attend)*
Gail Atkinson, University of Ontario
Cliff Frohlich, Univ. of Texas, Austin
Susan Hough, USGS, Pasadena *(did not attend)*
Andrew Michael, USGS, Menlo Park
Evelyn Roeloffs, USGS, Vancouver, WA
Allan Rubin, Princeton University *(did not attend)*
Peter Shearer, Univ. of California, San Diego
John Vidale, University of Washington
Michael Blanpied, USGS *(Secretariat/Designated Federal Officer)*

Presenters:

Nicholas van der Elst, USGS Earthquake Science Center, Pasadena, CA
Edward (Ned) Field, USGS Geological Hazards Science Center, Golden, CO
Joan Gomberg, USGS Earthquake Science Center, Seattle, WA
Jeanne Hardebeck, USGS Earthquake Science Center, Menlo Park, CA
Morgan Page, USGS Earthquake Science Center, Pasadena, CA

Registered Guests:

Ben Davidson, Space Weather News & The Mobile Observatory Project
Rob Woolley, IRIS